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U. S. DEPARTMENT OF AGRICULTURE,  
BUREAU OF ANIMAL INDUSTRY.—BULLETIN No. 93.  
A. D. MELVIN, CHIEF OF BUREAU.

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# THE RELATION OF TUBERCULOUS LESIONS TO THE MODE OF INFECTION.

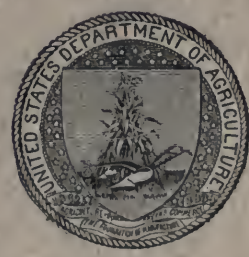
BY

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AND

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*Expert Assistant at Experiment Station,  
Bureau of Animal Industry.*

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## LETTER OF TRANSMITTAL.

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U. S. DEPARTMENT OF AGRICULTURE,  
BUREAU OF ANIMAL INDUSTRY,  
*Washington, D. C., November 3, 1906.*

SIR: I have the honor to transmit herewith, for publication as a bulletin of this Bureau, an article entitled "The Relation of Tuberculous Lesions to the Mode of Infection," by Dr. E. C. Schroeder and W. E. Cotton, of the Experiment Station of this Bureau.

In the experiments described in this paper, which were carried out mainly for the purpose of further testing the susceptibility of the lung to infection with tubercle bacilli regardless of the point at which the infectious material enters the body, tuberculosis was produced in the lungs of a calf and three hogs by inoculation near the end of the tail. This work, taken in connection with that reported in Bulletins Nos. 86 and 88 of this Bureau, indicates that the lungs may readily become the seat of tuberculous disease no matter thru what channel the bacilli gain entrance into the body, and that the location of lesions in the lungs can no longer be considered as reliable evidence that the infection entered thru the respiration.

Dried sputum has long been regarded as the most prolific agent in the dissemination of tuberculosis among people, but the facts presented in this bulletin, which are believed to have an important bearing on the problem of how tuberculosis is contracted by human beings, go to show that too much importance has been attached to this and not enough to the more serious danger from fresh or moist tuberculous material which enters human food in many ways, one of the commonest of which is attributable to the tuberculous dairy cow.

Respectfully,

A. M. FARRINGTON,  
*Acting Chief of Bureau.*

Hon. JAMES WILSON,  
*Secretary of Agriculture.*



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# THE RELATION OF TUBERCULOUS LESIONS TO THE MODE OF INFECTION.

## INTRODUCTORY.

It is an established and generally admitted fact that tuberculosis is more commonly an affection of the lung than of other organs or structures of the body. In a recent publication of the Bureau of Animal Industry<sup>a</sup> experimental evidence was presented to support the conclusion that this relatively greater frequency of pulmonary tuberculosis, as compared with other forms, is not due to the more direct exposure of the lung to infection that reaches it from without, suspended in the respired air, but to the more direct exposure of the lung to infection that may have entered the body in any way and has reached the lymph channels and, thru them, the blood stream.

To obtain further information on this subject and to trace more precisely the course taken by the infectious material from its point of entrance into the body to the lung, five animals—three hogs and two cattle—were given subcutaneous injections of virulent tubercle bacilli. The seat of injection selected as the most favorable for the purpose was the tail, as near the extreme end of it as possible, as this is the farthest removed available portion of the body from the lung, and the location from which the infection of the latter seemed least likely to occur.

## THE EXPERIMENTS WITH CATTLE.

The records of the two cattle above mentioned, together with an additional experiment on a calf; are as follows:

*Heifer No. 398.*—About 6 months old, in excellent condition. Tested with tuberculin without reaction. Injected April 6, 1906, subcutaneously, immediately above the brush at the end of the tail, with one-half cubic centimeter of a virulent bovine tubercle culture.<sup>b</sup>

*Bull No. 399.*—About 6 months old, in excellent condition, tested with tuberculin without reaction. Injected April 6, 1906, subcutaneously, immediately above the brush at the end of the tail, with 1 cubic centimeter of virulent bovine tubercle culture.

<sup>a</sup>Bulletin No. 86.

<sup>b</sup>The culture used is known in the laboratories of the Bureau of Animal Industry as Bovine III, and has been kept under artificial cultivation for a number of years.

The result from the injections was a slight induration at the ends of the tails. The cattle were killed on June 13, 1906 (sixty-eight days after the injections were made), and examined post-mortem. No lesions of disease were found excepting a few pearl-like nodules in the lungs, directly under the pleuræ, of both animals, and two such nodules in the liver of one animal. Microscopic examination showed the nodules to be little fatty tumors and wholly nontuberculous in character.

The absence of disease in the two cattle suggested the idea that an injection of the kind they received could be used for purposes of immunization against tuberculosis, and hence several young cattle were injected under the skin of their tails in a separate experiment relative to immunization. Among the animals, one (No. 461) died on the twenty-third day after injection. Its autopsy record, which is given below, is of special interest. The other animals of the group will be treated in a separate publication at a later date.

*Calf No. 461.*—Three months old, tested with tuberculin without reaction. Injected June 23, 1906, subcutaneously, at the end of its tail, with bovine tubercle culture (the tubercle bacilli used were Bovine III, the same kind as used for cattle Nos. 398 and 399). On July 15, 1906, the calf died, and on post-mortem examination the following lesions were found:

The tail, at the seat of inoculation, is slightly thickened, and the subcutaneous tissues are edematous, streaked with hemorrhagic lines, and contains irregular masses of necrosis.

One lymph gland, anterior to and a little to the right of the insertion of the tail, embedded in the coccygeal muscles, is  $1\frac{1}{2}$  by 1 by  $\frac{1}{2}$  inch in dimensions, and is edematous, intensely congested, and has the appearance of being affected thruout with very recent tuberculous disease. Microscopic examination of the gland shows innumerable tubercle bacilli. The corresponding gland on the left side is not more than a tenth as large, but otherwise in the same condition.

The superficial inguinal, prepectoral, prescapular, axillary, bronchial, mediastinal, gastro-hepatic, and mesenteric glands are edematous and marked with hemorrhagic lines and points. Microscopic examination of these glands shows innumerable tubercle bacilli in the superficial inguinal and mesenteric glands, a few in the mediastinal glands, one doubtful bacillus in two preparations from the bronchial glands, and not any in the other glands.

The entire lung has a firm, solid character and does not collapse at all. The lower halves of the cephalic and median lobes, the entire azygos lobe, and large patches in the principal lobes are of a dark red, hemorrhagic appearance. The whole lung, on surface and section, is densely and evenly sprinkled with minute yellow areas about one-thirtieth of an inch in diameter, which are made up of aggregations of very minute necrotic points. All the surface lesions are beneath the capsule, and the number of lesions is so great that more lung tissue is involved than is left unaffected. Microscopic examination of the little yellow areas shows the presence of innumerable tubercle bacilli.

The liver, spleen, kidneys, stomachs, and intestine are in apparently normal condition.

The case is a perfect picture of fatal miliary tuberculosis of the lung of recent origin, with a rapidly developing infection of the lymphatic

glands generally. The affection of the lung was so extensive that death was probably due directly to suffocation. The rapid character of the disease and the early fatal termination are attributable to the extreme susceptibility of this particular calf to tuberculosis.

#### THE EXPERIMENTS WITH HOGS.

The records of the three hogs are as follows:

Hogs Nos. 1383, 1384, and 1385 were tested with tuberculin without reaction on April 4, 1906, and each received on April 6, 1906, an inoculation of tubercle culture, Bovine III, under the skin covering the dorsal surface of the tail just anterior to its end. The hogs were killed a little more than two months later and examined post-mortem. The autopsy records follow:

*Hog No. 1383.*—June 12, 1906, killed and examined post-mortem. At the time of death the animal seemed very much distressed and gave the impression that it would die within a few hours. General condition very good, fat, weight about 200 pounds. The seat of the inoculation in the tail, about 20 cm. (8 inches) from its point of attachment to the body, shows considerable connective tissue thickening. The superficial inguinal glands contain several small tuberculous areas.

The lung is adherent to the chest wall and diaphragm, and the various lobes to each other. Sprinkled evenly over and throughout its entire substance are innumerable tuberculous masses from 1 mm. to 1 cm. in diameter; fully one-half of the lung tissue is destroyed. The pulmonary and costal pleuræ and the thoracic surface of the diaphragm are thickly studded with innumerable tubercles from 1 mm. to 1 cm. in diameter.

The convex surface of the liver is sprinkled with minute tubercles; a similar but less marked condition is found on the concave surface. No tubercles were found in the parenchyma of the organ.

No lymph-gland disease was found in any part of the body excepting that recorded in the superficial inguinal glands.

*Hog No. 1384.*—June 13, 1906, killed and examined post-mortem. General condition very good, fat, weight about 200 pounds. The tail, about 25 cm. (10 inches) from its point of attachment to the body, at the seat of inoculation, is somewhat thickened. On section the increased connective tissue is found to be sprinkled with a dozen or more minute necrotic foci, less than one-half mm. in diameter. One of the superficial inguinal glands contains a few tuberculous foci.

The lung is adherent to the chest wall and to the diaphragm. The costal and pulmonary pleuræ and the thoracic surface of the diaphragm are closely sprinkled with small tubercles which vary in size from points to 3 mm. in diameter. The cephalic lobes on both sides, the entire left median lobe, the anterior and dependent portions of the right median lobe, and the anterior portions of both principal lobes are completely solidified and tuberculous throughout; the balance of the lung is sprinkled evenly with innumerable tuberculous areas from 1 mm. to 1 cm. in diameter. The bronchial glands on both sides are greatly enlarged and sprinkled with a small number of very minute necrotic foci.

The liver is evenly sprinkled with innumerable foci of tuberculosis, 2 mm. and less in diameter. The gastro-hepatic chain of lymph glands are enlarged and sprinkled with minute foci of tuberculosis. The spleen contains a sprinkling of tuberculous foci.

*Hog No. 1385.*—June 13, 1906, killed and examined post-mortem. General condition very good, fat, weight about 200 pounds. The tail, about 20 cm. (8 inches)



from its point of attachment to the body, at the seat of inoculation, is somewhat thickened, and has on its lower surface a flat sore about 2 cm. in diameter. On section the thickening is found to be due to an increase in the amount of connective tissue.

One of the right superficial inguinal glands is enormously enlarged, fully ten times its normal diameter, and completely tuberculous. The corresponding gland on the left side is slightly enlarged and contains a few tuberculous foci.

The lung is adherent to the chest wall by a number of fine connective tissue threads. The entire organ is densely and evenly sprinkled with innumerable tuberculous masses from 1 to 5 mm. in diameter. The tubercles are so numerous that fully one-third of the entire lung tissue has been displaced by them.

The liver contains about a dozen minute tubercles 1 mm. and less in diameter.

Spleen contains about a dozen tubercles less than 1 mm. in diameter.

No lesions of the lymph glands were found excepting those recorded for the superficial inguinals.

#### THE COURSE OF THE INFECTION FROM TAIL TO LUNG.

The post-mortem examinations of the three hogs and the one calf that became affected with tuberculosis show the most extensive lesions in the lung in every case. When we bear in mind that this resulted from tubercle bacilli introduced into the bodies of the animals by subcutaneous inoculations at the ends of their tails, we are justified in concluding that one of two courses was taken by the bacilli to reach the lung: (1) They were taken up by the capillary blood vessels and carried to the lung directly with the venous blood stream; or (2) they were taken up by the lymph radicals, past along the lymph channels by or thru the lymph glands, entered the great thoracic duct, and thru it were poured into the venous circulation.

Once tubercle bacilli have entered the venous blood stream there is nothing in the way of the direct infection of the lung except, first, smooth-walled vessels of constantly increasing caliber, second, the smooth-walled chambers of the heart, and third, the smooth-walled pulmonary arteries that end in the exceedingly fine, thin-walled, complex capillary system of the lung, the anastomosis of which is so complete and the close and intricate intercommunication so frequent that it is not difficult to conceive of individual vessels in which perfect stasis may occur.

The destruction of tubercle bacilli by leucocytes or phagocytes after they have entered the blood does not require consideration in this connection, nor the attenuation of the bacilli by the germicidal action of the blood for various other species of bacteria. If these were factors of importance against the infection of an organ with tuberculosis it would have been impossible, as has been done in some of our earlier work,<sup>a</sup> to demonstrate the persistence of live tubercle bacilli of an original virulence too low to cause a progressive affection in the tissues of cattle for periods of time varying from three months to two years.

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<sup>a</sup> Bureau of Animal Industry Bulletin No. 52, Part III.

In this connection it may be interesting to give an observation made at the Experiment Station on two cows, each of which received an injection of tubercle bacilli into a quarter of her udder thru her teat in a manner specially devised to prevent the occurrence of a trauma. The one cow received live tubercle bacilli of low virulence and the other dead tubercle bacilli of the same strain. As a result of the injections the udders of both cows were considerably affected and secreted a creamy, slightly viscid, fluid, which contained innumerable leucocytes. The cow that received the dead bacilli recovered completely in about two months, and the cow that received the live bacilli, while she made an apparent recovery in about eighteen months, continues to secrete tubercle bacilli, virulent for guinea pigs at this date, four years and ten months after injection.

The microscopic examinations of the secretions from the injected quarters of the udders of the two cows showed that the dead tubercle bacilli were almost invariably located within leucocytes, and that the live tubercle bacilli were rarely located in the leucocytes and almost invariably floated free in the fluid in which the leucocytes were suspended. Additional experiments are now in progress to determine whether this is always the case with tubercle bacilli in the udders of cattle.

Relative to the course followed by the infectious material in the four tail-injected animals we have the following facts: (1) The excessive disease in the lung in all cases; (2) the presence of superficial inguinal disease in all cases; (3) the infection of the liver in the three hogs, but not in the calf; (4) the infection of the spleen in two hogs; (5) the infection of the bronchial glands in one hog and in the calf, and, (6) in addition to the infection of the lung, superficial inguinal and bronchial glands, the infection in the calf of the coccygeal, mesenteric, and mediastinal glands; and, in addition to the infection of the lung, superficial inguinal glands, liver, spleen, and bronchial glands in one hog, an infection also of the gastro-hepatic glands.

From this we may conclude that the infectious material, after it had been taken up by the lymph radicals in the tail, passed more or less directly to the superficial inguinal glands, which filtered out and retained some of the bacilli. The two glands at the root of the tail in the calf evidently have a position in the lymphatic chain between the tail and the superficial inguinal glands. Whether the disease in the mesenteric glands of the calf was due to direct transmission of infection to them from the seat of inoculation, or was due to bacilli coughed up from the lung and swallowed and passed thru the intestinal wall, could not be definitely determined. The infection of the liver and spleen is probably secondary and followed after the infection of the lung. The less amount of disease in the livers of the hogs and its entire absence in the calf bears out this assumption. The same is

true of the disease in the spleen, which was slightly affected in two hogs and normal in one hog and in the calf.

As with our previously published experiments in which hogs received injections of virulent tubercle bacilli subcutaneously in the abdominal region,<sup>a</sup> and the experiment in which hogs contracted tuberculosis thru eating artificially infected milk,<sup>b</sup> it is shown with these injections that tubercle bacilli may pass from portions of the body remote to the lung fairly directly to it and cause pulmonary tuberculosis. And this passage may occur without the formation or development of a well-marked chain of lesions along the path followed by the bacilli from the point of entrance in the body to their localization in the lung.

#### SOME CORROBORATIVE EVIDENCE OF OTHER INVESTIGATORS.

That tubercle bacilli can pass thru lymph glands, along lymph channels into the great thoracic duct, and thru it into the venous circulation, from which the infection of the lung occurs, is receiving, in addition to the evidence drawn from our own experiments, the strongest support from the work of other investigators.

According to a résumé of their work in a recent number of the Medical Record,<sup>c</sup> Schlossman and St. Engle have expressed practically the same conclusion. They drew it from the occurrence of tubercle bacilli in the lungs of guinea pigs into the stomachs of which an emulsion of tubercle bacilli was introduced by means of a laparotomy especially made to exclude the direct infection of the air passages or lung.

Calmette is quoted in the British Medical Journal<sup>d</sup> to have observed that pigment ingested by adult animals found its way at once to the lungs, while that ingested by young animals was first stopped by the mesenteric glands, and that he had produced a case of pulmonary tuberculosis without lesions of the gastro-intestinal mucosa or the mesenteric glands by introducing suspensions of tubercle bacilli into the rumens of goats.

#### THE INHALATION AND INGESTION METHODS OF INFECTION CONTRASTED.

The practical conclusion to be drawn from the results obtained is that ingestion is a greater danger than the respiration of tubercle bacilli, especially as the tubercle bacilli may be ingested in the fresh state in which they are expelled from tuberculous lesions and can not be respired until they have been subjected to various attenuating

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<sup>a</sup> Bureau of Animal Industry, Bulletin No. 86.

<sup>b</sup> Bureau of Animal Industry, Bulletin No. 88.

<sup>c</sup> Vol. 70, No. 5, p. 191.

<sup>d</sup> No. 2359, March 17, 1906, p. 623.



processes. The substance in which tubercle bacilli are enveloped or embedded when they leave the infected organs under ordinary and usual conditions requires considerable time before it can be sufficiently dried and pulverized to float in the air. Bacilli do not rise from moist surfaces and float in the air. The complete desiccation that must occur in advance of pulverization is either a comparatively slow process or is hastened by agencies, like the heat from the direct rays of the sun, that have a potent influence against the vitality of pathogenic bacteria. Sputum, for example, dries on the surface in a way that coats it with a protective membrane thru which evaporation progresses slowly; it is a very adhesive substance and becomes more so during the first stages of drying, and it must be exposed when thoroly dried to actual attrition before it can be detached from the surface on which it has dried and reach a sufficient disintegration to be blown about as dust.

#### THE THEORY OF INFECTION BY INHALING DRIED SPUTUM.

Dried, pulverized sputum has long been regarded as the most prolific and important agent for the dissemination of tuberculous infection. Koch, in his Nobel lecture delivered at Stockholm on December 12, 1905,<sup>a</sup> declared that only those tuberculous patients who suffer from laryngeal and pulmonary tuberculosis and whose sputa contain bacilli are dangerous to those around them in a noteworthy degree.

On the other hand we learn from the investigations of Cadéac<sup>b</sup> that the hypothesis of the transmission of tuberculosis by inhalation of the dust from dried sputa has not been proved. He found that expectorated matter dried slowly and was neither simple nor easy to convert into dust; that sputa spread thickly on a glass plate and exposed to natural light adhered as a bright varnish and was not easily powdered into dust until the tenth or twelfth day, and that even on the sixth day a considerable quantity of powdered sputum was required to cause a discrete tuberculosis on peritoneal injection of guinea pigs. Sputum spread on a marble plate and kept above a stove for fourteen days was found to have lost its virulence for guinea pigs, and spread on a porous plate and exposed to sunlight it was not effective for inoculation after forty-eight hours. Dried in the dark, some virulence was retained.

#### THE MORE SERIOUS DANGER FROM FRESH AND MOIST TUBERCULOUS MATERIAL.

We gather from these various facts that too much importance has been given to dried and pulverized, and not enough to fresh and moist tuberculous material. The respiratory theory to account for the relatively great frequency with which tuberculosis is localized in the lung

<sup>a</sup> The Lancet, May 26, 1906.

<sup>b</sup> Lyon Médical, December 10, 1905; British Medical Journal, March 10, 1906.



really requires dried and pulverized sputum to give it a reasonable footing, and if pulverized sputum is shown to be inert the theory has nothing left to stand on. With the respiratory and inhalation theory shown to be unnecessary to account for the infection of the lung, and the outline we have given of the manner in which the lung becomes infected, fresh and moist tuberculous material must be given a place of primary importance, and exposure to it must be persistently avoided and regarded as the exceptionally great danger. This can not be too much emphasized.

Exposure to fresh and moist material that contains tubercle bacilli occurs probably with great frequency, thru the ingestion of food that has been handled and prepared by persons affected with tuberculosis. To quote again from Koch's Nobel lecture, previously referred to, we have the following:

Attention must be paid to the fact that it is not only the secretion of the lungs called sputum that is dangerous as containing bacilli, but that according to the investigations of Flugge the smallest droplets of phlegm that are thrown into the air by tuberculous persons when they cough, clear their throats, and even when they speak, also contain bacilli and can cause infection.

What more fruitful source of food infection with tubercle bacilli can exist than that implied in the foregoing quotation, when the culinary operations of a household are intrusted to a tuberculous person, whether servant or member of the family, or when the food in an eating-house or hotel is prepared by a tuberculous cook or a cook with a tuberculous assistant, or when food is exposed to no further means of contamination than a tuberculous waiter, who breathes over cold and hot dishes alike, commonly with perfect ignorance and disregard of the insidious but fatal poison that may escape from his mouth with every word he speaks and every accelerated expiration that passes his lips?

#### **THE FACILITY WITH WHICH BACILLI FROM TUBERCULOUS COWS MAY ENTER HUMAN FOOD.**

Altho authorities are not in accord on the intertransmissibility of human and bovine tuberculosis, we feel that it is necessary to call attention to one way in which tubercle bacilli, scattered by tuberculous cattle, are undoubtedly often introduced into human food.

Tuberculosis of men and cattle was universally regarded as etiologically the same affection until Dr. Theobald Smith, of America, pointed out a morphological difference between tubercle bacilli isolated from human and bovine lesions, and Dr. Robert Koch, of Germany, later on, characterized bovine tuberculosis as a disease that could be almost, if not entirely, ignored as a source of infection dangerous to man.

Opposed to the view of Doctor Smith is the frequent isolation of bacilli from human tuberculous lesions that are morphologically of the bovine type. This circumstance may be interpreted to mean one of

two things—either that persons who succumb to tuberculosis due to bacilli of the so-called bovine type were infected from cattle, or that the difference between the so-called human and bovine types has a significance similar to that of the morphological variation common with most bacteria.

Doctor Koch's assertion that cattle tuberculosis is a negligible quantity in the measures that must be taken for the preservation of human health is based largely, if not wholly, on negative evidence, or, strictly speaking, no evidence at all. He, as well as many other investigators, found that it was difficult to induce tuberculosis in cattle by exposing them to or injecting them with tubercle bacilli obtained from human sources, and concluded from this that man was equally resistant to tubercle bacilli obtained from bovine sources. The premise does not justify the conclusion, and the mass of circumstantial evidence that is contrary to its acceptance is extremely voluminous and convincing.

Many tubercle bacilli have been isolated from human lesions that are more infectious for cattle than many tubercle bacilli isolated from bovine lesions, and it is now pretty generally admitted that tubercle bacilli from bovine sources as a rule have a higher virulence than tubercle bacilli from human sources for all animals with which they have been tested. The animals tested include several species of the quadrumania, which are certainly much nearer to man, anatomically and physiologically, than to cattle.

It would be curious indeed if man were an exception to a rule that has been found by conclusive tests to be applicable to the animal nature of all the species of the mammalian kingdom to which man belongs. To establish definitely that one species is an exception to a condition that is true of all the tried species of a great kingdom should require preponderating evidence, and can not be settled with negative evidence or a simple process of reasoning from analogy. In fact, it is not a process of reasoning at all with which we are dealing; it is a simple assumption to say that a being which is ordinarily affected with a weaker virus of a special kind is immune against the stronger virus usually found in connection with another being, simply because the being with the stronger is to some extent immune against the weaker virus.

The commonly lower virulence of tubercle bacilli from human lesions may be due in part to the comparatively greater care bestowed on sick persons, and the general treatment, medical and other kind, that they receive, which prolongs their lives and the duration of the affection, and consequently exposes the virus to possible modifying influences of a biologic order. This seems more probable, since it has been shown that the disease has the elements of a self-limited affection, by the fact that it is possible to induce an immunity against tuberculosis by the injection of tubercle bacilli of a virulence too low to cause a progressive tuberculosis.

But we do not wish to enter into a long argument on this question, and must return to the subject of tubercle bacilli from cattle that may enter human food. We believe that we have said enough to show that it is desirable in every sense of the word to protect our health against tuberculous infection from cattle and to know thru what channel it may reach us. We are compelled to maintain this view, tho it is opposed to the opinion of Doctor Koch, of the inestimable value of whose general work on tuberculosis we have the highest appreciation and sincerely feel and believe that it gives him the rank of a public benefactor of the first order.

It has been shown by our work at the Experiment Station during the past year, an account of which will be published in a separate article, that the main channel thru which tubercle bacilli leave the bodies of tuberculous cattle is the rectum, and that feces may be regarded as a parallel substance with cattle to sputa with man in the dissemination of tubercle bacilli. This was demonstrated thru microscopic examinations and inoculation tests with small animals.

The feces not only of cattle affected with advanced tuberculosis, but also of a large percentage of those so slightly affected that their tuberculous condition was not suspected until they had been tested with tuberculin, were found to contain a sufficient number of microscopically discoverable tubercle bacilli to equal many millions in the total mass of feces past by a single cow each day. The bacilli were found to be evenly distributed in the feces, which is fairly good evidence that they had past thru the greater portion, probably the entire length, of the digestive tract. This even distribution was similar to that of the bacilli in the feces of healthy cattle that were given water to drink to which tubercle bacilli had been intentionally added. That the bacilli were virulent was proved by causing tuberculosis to develop in guinea pigs by inoculating them with feces and with milk soiled with feces from naturally tuberculous cows, as well as from the healthy cows that drank water to which tubercle cultures had been added.

Now, if many millions of tubercle bacilli are commonly past by tuberculous cows, evenly distributed in their feces, which we have definitely convinced ourselves to be the case, it is not difficult to see that, because of the intensely infected environment of tuberculous cattle, it is no easy matter to obtain milk at all times free from tubercle bacilli. How easily feces, and with them tubercle bacilli, may be introduced into the milk pail no one who has witnessed the milking of cows need be told.

#### CONCLUSIONS.

(1) We believe that we have shown that systematic investigation is gradually retiring the inhalation theory that has long been used to explain the frequency with which tuberculosis is a pulmonary disease



and that the ingestion of tubercle bacilli is being proved to be the real method thru which tuberculous infection reaches the lung, as well as other organs of the body.

When substances of dissimilar specific gravity move at the same rate of speed under similar conditions, it is a physical fact that the force required to change their direction is proportionately greater as the specific gravity increases. If the substances of dissimilar specific gravity are air and dust and the change of direction is due to movement thru the far-from-straight, moist-walled passages from the nasal openings, or even the mouth, to the lung, the dust will be thrown at every turn, because of its greater specific gravity, against the walls of the air passages, to which it will adhere because they are moist, and the ciliated epithelium with which the respiratory passages are lined will tend to move the adherent particles outward and not inward. It is, hence (excepting, possibly, with extremely forcible inspiratory movement in a dust-saturated atmosphere), almost a physical impossibility for dust particles to penetrate with the air into the lung. If no other argument than this could be brought to bear against the inhalation theory of pulmonary tuberculosis—and it applies with equal force against inhalation of other infectious material, including the microorganisms of pneumonia—it would be sufficient to condemn it.

(2) Not only is the inhalation theory dying and making room for the fact that ingestion is the true mode of infection with tuberculosis, but the theory that dust from pulverized sputa is the most important factor in the transmission of tuberculosis from subject to subject is gradually losing ground also and giving way to the conviction that fresh tuberculous material must be looked to as the true agent thru which infection occurs.

(3) While many cases of tuberculosis undoubtedly have their origin thru food directly or indirectly infected with fresh tuberculous material by tuberculous persons, there is no means to-day by which persons are brought into closer contact with fresh tuberculous material than milk and dairy products obtained from, and in the environment of, tuberculous cows. The wide use of milk, its rapid distribution because of its perishable character, the ease with which it may be contaminated by having tubercle-bacilli-laden feces splashed, sprayed, switched, or otherwise introduced into it in a fresh state, all speak for one conclusion, namely, that we have no more active agent than the tuberculous cow for the increase of tuberculosis among animals and its persistence among men.

#### SUMMARY OF THE CONCLUSIONS.

The main facts are as follows:

(a) Tuberculosis is a disease contracted thru the ingestion of tubercle bacilli.

(b) The lung is the most frequent organ affected, independently of the point at which the infectious material enters the body.

(c) Tuberculous infection may pass from one part of the body to another remote to it without leaving a chain of lesions to mark its path.

(d) Fresh tuberculous material has the highest, and dried and pulverized material a doubtful significance.

(e) Tuberculous material from cattle has the highest virulence for all tested species of the mammalian kingdom, to which man anatomically and physiologically belongs, and tuberculous material from man has a lower virulence.

(f) Man is constantly exposed to fresh tuberculous material in a helpless way thru his use of dairy products from tuberculous cows and cows associated with tuberculous cattle.

It seems from this array of facts, every one of which is based on positive experimental evidence, that we should feel no doubt regarding our plain duty, which is, no matter what other measures we adopt in our fight against tuberculosis, not to neglect one of the chief, if not the most important, source of infection—the tuberculous dairy cow.

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#### ADDENDUM.

##### RECENT WORK BY A FRENCH INVESTIGATOR.

Since concluding this article a recent paper by Cadéac has appeared in *Le Bulletin Médical* of September 5, 1906, of which the following résumé was given in the *New York Medical Record* of October 6, 1906, and it seems desirable to quote it here, because of its important bearing on the relative danger to health represented on the one hand by exposure to dried and pulverized, and on the other by exposure to moist and fresh tuberculous material:

Cadéac declares that the dust ground from dried tuberculous sputum is harmless both to the digestive and respiratory passages. Not a single experiment has shown the transmission of tuberculosis by the inhalation of dust gathered from localities inhabited by tuberculous patients. The writer has demonstrated that it is almost impossible to cause the development of this disease by the inhalation of this infected dust. The desiccation and rapid conversion of sputum into flying dust are the natural means of preservation against tuberculous infection.

Here we have a double argument, equally potent against the inhalation theory of pulmonary tuberculosis and in favor of the greater danger from exposure to fresh and moist tuberculous material. As we have already said, without dried and pulverized infectious material the inhalation theory has absolutely no foundation on which it can reasonably stand; and, if dried and pulverized material is as inert as the investigations of Cadéac represent it to be, fresh and moist material for men and animals alike must be looked to as the true cause for the

transmission and persistence of tuberculosis. The inhalation theory, and the great importance attached to dust as an agent for the transmission of tuberculosis, are beginning to have the appearance of two errors that have long hampered the fight that is being made against tuberculosis. A clear comprehension of the many ways in which fresh tuberculous material, the infectious potency of which is unquestionable, can be introduced into articles of food used by man and animals, shows conclusively that this is sufficient to account for the frequency with which infection occurs and the widespread character of the disease.

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